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Using a Videographic System to Assess Spray Droplet Impaction and Reflection from Leaf and Artificial Surfaces‡

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Abstract: A video motion analysis system was used with two different monodisperse droplet generators to quantify droplet impaction and any consequent reflection. By using different magnification/droplet generator combinations, droplet impaction was detailed at various stages. Low (7×) magnification, together with a generator that produced a spray cloud, allowed determination of the height and numbers of droplets reflected from plant surfaces. Higher (15×) magnification and a single-drop generator enabled the trajectory, and changes in velocity, of a rebounding droplet to be followed. By using high (90×) magnification and the single-drop generator, detailed measurements of a droplet deforming on impact could be made. Examples of how these techniques could be used are given. © 1998 SCI

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Key words: reflection; impaction; droplet generators; leaf surfaces

1 INTRODUCTION

Application of foliar sprays is a complex process that includes such events as spray atomization, transport to the plant, impaction on plant surfaces, retention, and for systemic compounds, uptake by the plant.[1–4] These processes all influence spray effectiveness. Droplet retention on a plant surface is only one stage in the application process, but it is critical since only retained spray is useful for crop protection, while reflected spray can result in economic loss and contribute to environmental contamination.

Whether a droplet is retained or reflected by a plant surface is a function of the properties of the spray solution (surface tension and viscosity), spray pattern (droplet size and velocity),[2,5–9] and the surface morphology (degree of pubescence, venation, fine-structure) and chemistry of surface functional groups of the target surface.[3,10–13]

We propose that a better understanding of the role of spray additives, delivery systems and plant surfaces on spray efficacy can be achieved by improved measurement of droplet reflection. Reichard[14] used high-speed motion photography and an analytical projector to observe and analyze the impaction of uniform-sized droplets from a spray cloud. This paper describes the use of a video motion analysis system in conjunction with two different droplet generators to observe droplet impaction. The new technology enables many replicates of high resolution images to be captured, stored and analyzed quickly and easily. The objective of this study was to develop techniques for examining and quantifying droplet impaction and reflection. Results presented here are given as an indication of the types of study

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possible using the techniques described. They do not attempt to explain all aspects of the impaction process.

Three techniques were developed; all used monosized droplet generators coupled with a high-speed video system to capture droplet images. By varying the type of generator (single-droplet or spray cloud), lighting and camera magnification, one particular aspect of the impaction process could be examined in detail. For example, when a single droplet was viewed at the air/surface interface using high magnification it was possible to capture images of the impaction process immediately before and during droplet impaction, and droplet recovery or reflection. If lower magnification was used, the trajectory of the incoming and reflected droplet could be followed, making possible the calculation of droplet velocity before and after impaction as well as reflection height. Using low magnification with a generator that produced a monosized droplet spray allowed accurate measurement of the height and count (or under some conditions a reasonable estimate) of the number of droplets reflected from a given surface.

2 EXPERIMENTAL METHODS

2.1 Spray application

2.1.1 Drop-on-demand generator

A drop-on-demand (DOD) generator, similar to that developed by Young,[15] was constructed to produce single, monosized droplets.[16] Electron microscope apertures were used to produce droplets from 100 to 500 μm in diameter, while square-cut hypodermic needles ranging from size 26 through 22 were used to produce droplets from 400 to 800 μm in diameter. Thus the drop sizes obtainable were representative of those produced under many field conditions, but were not representative of the smaller droplets (<100 μm) produced by air-assisted sprayers.[17] The variability in droplet size and velocity produced by this generator was less than 4% and 6%, respectively. All droplets had negligible velocity close to the orifice; thus, in order to obtain a range of incoming velocities, the target was placed at varying vertical distances from the orifice. Maximum possible velocity for a given drop size was its terminal velocity, for example, 0.25 m s^{-1} for a 100-μm droplet and 1.20 m s^{-1} for a 300-μm droplet. As orifice-to-target distance increased, the droplet flight was affected by air movement. This was undesirable since, at the magnifications used, the field of view of the video system was limited, and accurate placement of the droplet was necessary to obtain a focused image. Cardboard tubes were mounted beneath the generator when necessary to shield droplets from air currents.

The advantages of this system are the ability to produce single droplets that can be precisely placed on different parts of the target surface, in a range of sizes commonly used in pesticide application. The system can also be used to follow the trajectory (and thus calculate the velocity) of incoming and reflecting droplets, and to determine reflection height. A disadvantage of the system is the inability to produce high-velocity droplets. It can only be used to describe what happens to droplets traveling at terminal velocity or slower, for example, at some distance from the sprayer or after the initial droplet impaction.

2.1.2 Berglund-Liu generator

A Model 3050 Berglund-Liu (BL) vibrating monodisperse aerosol generator (TSI, St. Paul, MN 55164) was modified to produce a stream of monosized droplets[18] in the size range of 50–1500 μm. Variation in droplet size and velocity from this machine was less than 1%.

A brass ring positioned approximately 1 cm below the orifice, at the point where the ligament first broke up into droplets, was operated at a DC voltage to induce droplet charges sufficient only to disperse the droplet stream, providing a spray cone covering approximately 1 cm^2 at the impaction site. A trough was positioned just below the orifice to collect the spray while the plant material was positioned and video system readied. Thus impaction always occurred on new, dry surfaces.

An advantage of the BL over the DOD generator is the production of a spray cloud, compared to a single droplet, which more closely simulates hydraulic nozzle applications. The velocity of droplets produced by the BL generator is less than those used in the field, e.g. a 250-μm droplet would typically have a velocity of 7.0 m s^{-1} when produced using the BL generator, compared to 20 m s^{-1} measured directly beneath the orifice of a typical hydraulic nozzle operated at 40 psi.[19] However, droplet velocity just above the crop, typically 45 cm beneath the nozzle, would have decreased to under 5 m s^{-1} (Downer, R.A., 1997, pers. comm.) which is comparable with that obtained from the BL. A further advantage is the ability to determine the proportion of incoming droplets reflected from a given surface, along with reflection height.

2.2 Video motion analysis system

The video motion analysis system (VMAS) was equipped with a monochrome video camera (Model VC-81D, DAGE-MTI,Inc., Michigan City, IN 46360) with a newvicon tube and a high resolution imaging board (Model 4MEG, EPIX, Inc., Northbrook, IL 60062) controlled by a menu-driven motion analysis software package 4MIP (EPIX, Inc.), which provided basic video operations along with a wide selection of image examination, processing, and measurement operations.[20]

The imaging board was operated at 24.0 MHz and provided the necessary timing pulses to drive the camera at 60 fields per second. This resulted in a non-interlaced (field) image resolution of 640 × 240 pixels on a high resolution monitor (Model MR2000, DAGE-MTI, Inc.). At this resolution, 27 successive images could be stored in the memory buffers on the imaging board. EPIX software was used to calculate accurate horizontal and vertical magnification. Moveable rulers could be drawn on the screen, and used to measure image features such as droplet diameters, height of reflection from the surface, and distance between successive images of the same droplet.

2.3 Droplet illumination

To study droplet reflection, a single stroboscope (Type 1538-A, Genrad, Concord, MA 01742) was used to back-light droplets produced using the DOD generator. The flash rate of the strobe was approximately seven times the field-sequential rate used to drive the camera, thus producing multiple images of the same droplet in a single frame (Fig. 1).

To illuminate an incoming droplet spray from the BL droplet generator, two stroboscopes were placed 0.05 m behind, and to either side of, the target leaf at approximately 45° to the longitudinal axis of the camera. The strobe was used at a flash rate higher than the field rate of the camera, so that several images of the same droplet were visible in each frame. Trajectories of reflected droplets were defined by the tracks of sequential images of each droplet (Fig. 2).

2.4 Droplet impaction

Droplet impaction and deformation were studied on the non-reflective surface of a glass microscope slide. An STI 3030-series pulsed light-beam proximity detector (Thorrat and Hanmer, Cleveland OH 44116) was placed between the DOD orifice and the glass slide. Each time a droplet passed through the beam it triggered a single flash of the strobe. By specifying the time interval between the triggering of the beam and the flash of the strobe, the position of the droplet relative to the target when the droplet was illuminated could be varied. By increasing the time in small (0.1 ms) increments it was possible to record the impaction process in detail from before impaction, through maximum deformation, to droplet recovery. Five 330-μm water droplets, each with an incoming velocity of 0.65 m s^{-1}, were videographed at each time interval.

2.5 Rebound measurements

2.5.1 *Drop-on-demand*

Reflection height and in-flight diameter of the droplets were measured on the monitor, while velocities, both incoming and rebounding, were calculated. For any treatment, whether droplet size, surfactant or plant species, replication consisted of a single droplet impacting onto a new, freshly prepared leaf surface. Ten replicate measurements were used per variable. For the intra-species experiment, replication consisted of ten single-droplet impactions each on a new dry area of the same leaf for each variable.

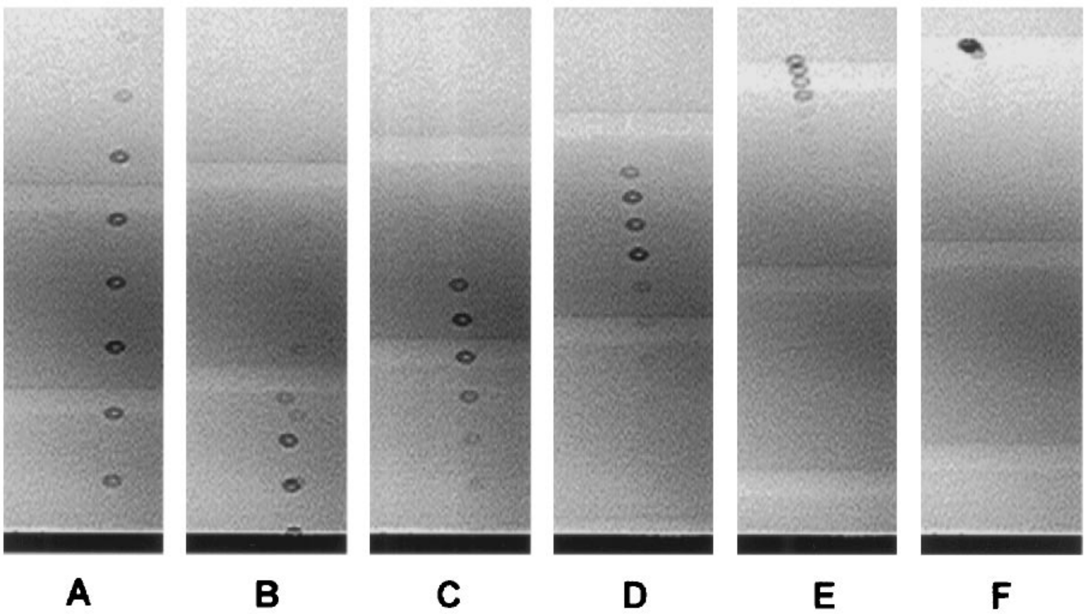

Fig. 1. Composite of videographs illustrating an incoming and reflecting water droplet (340 μm, 0.7 m s^{-1}) during impaction on the adaxial surface of a wheat leaf. (A) incoming, (B) impacting, (C-E) trajectory of rebound, (F) at maximum reflection height. Droplet produced using DOD generator.

Fig. 2. Reflection of water droplets (340 μm, 7.0 m s^{-1}) from the adaxial surface of a wheat leaf, BL-generated spray.

The velocity of droplets produced using the DOD generator was determined directly from the monitor by dividing the distance between successive images of the same droplet by the flash rate of the strobe.

The trajectory of the reflected droplet was seldom vertical, but angled. Since this angle varied within and among species, the theoretical vertical reflection height was calculated and used to compare reflection heights in all cases. Theoretical reflection height, h (m), was calculated from:

$$h = v^2(2g)^{-1}$$

where v is the velocity of the rebounding droplet immediately after impaction (m s^{-1}), and g the acceleration due to gravity (9.81 m s^{-2}).

2.5.2 Berglund-Liu

Successive images, 16.6 ms apart, of the impaction process were captured from before any droplets impacted until the leaf was thoroughly wet. The single image that depicted the first droplets impacting on a previously non-sprayed surface was used for analysis. The heights of the 20 highest rebounding droplets were recorded for each replicate, along with a count or estimate of the number of droplets reflected. Ten replicates were used per variable. To determine rebound height, an overlay of a horizontal line (an EPIX software feature) was moved slowly from top to the bottom of the image. When the line coincided with a droplet which was at its maximum rebound height the droplet position was recorded. The line was then moved downward until the heights of 20 droplets had been recorded. Individual droplets could be distinguished easily when few droplets rebounded, but when many droplets rebounded, the frame was studied and number estimated.

2.6 Plant material

Plant species used were cabbage (*Brassica oleracea* L. cv. Wisconsin All-Season), wheat (*Triticum aestivum* L. unknown (trial) variety), giant foxtail (*Seteria faberi* Herrm.), soybean (*Glycine max* L. cv. Clark) and pear (*Pyrus communis* L. cv. Bradford). All plants were previously untreated. Leaves uniform in development and free of damage were selected for all species. All plants were greenhouse grown, with the exception of pear, the leaves of which were collected from a single pear tree growing on campus. A small ($\sim$0.03 × 0.01 m) portion of each leaf was excised and placed, adaxial surface up, on a glass slide covered with double-sided tape. This held the leaf flat so that the edges did not obscure the site of impaction from the camera. Preliminary experiments showed the same deposition whether the tape was used or not. However, a single, flat, stationary leaf would not be a typical target in the field. This laboratory procedure would probably result in a higher deposit than would be obtained under field conditions. The leaf was then positioned directly underneath a droplet generator orifice and sprayed. For the DOD generator, the orifice-to-target distance varied (0.02–1.0 m) with the study; with the BL generator, the distance was 0.12 m.

2.7 Magnification

For videographing droplet reflection from a BL-generated spray, a Micro-Nikkor 55 mm f/2.8 lens was used to produce an on-monitor magnification of approximately 7 ×. For studying the reflection of single droplets, greater magnification was required and the lens was reversed to give a magnification of approximately 15 ×. When viewing images of impacting droplets a magnification of 90 × was used.

2.8 Surfactants

The surfactants used (Table 1) were representative of those commonly used for crop production; all were tested at a typical field rate of 1.25 mg litre^{-1} except where noted. The water used in all studies was distilled and deionized and had a surface tension of 72 mN m^{-1} at 25 °C.

2.9 Impaction/reflection energy

Detailed discussions of droplet deformation and recovery have been presented elsewhere.[13,22,23] Briefly, droplet impaction/reflection action is governed by the way the source kinetic energy of the incoming droplet is partitioned during impaction. When the droplet impacts on a surface, kinetic energy is transformed into other forms of energy such as potential energy of the stretched droplet surface, potential energy of deformed leaf-surface waxes and the deflection of the leaf itself. Energy loss can occur within the droplet, at the interface between the droplet and leaf surface, or to the leaf itself. Reflection of a droplet occurs when a reforming droplet has sufficient stored energy to overcome adhesion forces and droplet weight (potential energy) to impart a reflection velocity to the reformed droplet. Any change in droplet characteristics (incoming velocity, viscosity, surface tension), leaf surface structure or other energy sources and sinks will affect reflection velocity and height. It is difficult to determine the physical properties of the spray mixture that relate to the dynamic conditions of droplet rebound. Also, the surface nature of individual leaves may vary greatly from area to area and with leaf age, so a definitive energy-balance model of droplet impaction has not been developed.

3 RESULTS AND DISCUSSION

3.1 Droplet impaction

Water droplets (330 μm diameter) travelling at 0.65 m s^{-1} were impacted upon a glass surface. A selection of droplet images is shown in Fig. 3; each image is the one best described by the mean height of all five droplets at the respective time interval. Droplet height decreased to a minimum (i.e. maximum deformation) approximately 0.5 ms after impaction (Fig. 4). Height then increased as the droplet started to return to a spherical shape, but energy loss during impaction was too great to support reflection. If the surface had been reflective, it can be seen from Fig. 4 that the droplet would have left the surface in less than 1 ms.

TABLE 1
Brief Description of Nonionic Surfactants Used

Surfactant	*Source*	*Principal active ingredient*[21]
Agridex	Helena Chemical Co.[a]	Blend of paraffin base petroleum oil, polyol fatty acid esters and polyethoxylated derivatives. Components ineffective as a spray adjuvant 1%.
Induce	Helena Chemical Co.[a]	Blend of alkyl polyoxyalkane ether, free fatty acids and isopropanol. Components ineffective as a spray adjuvant 10%.
Kinetic	Helena Chemical Co.[a]	Blend of polyalkyleneoxide modified polydimethylsiloxane and nonionic surfactants. Components ineffective as a spray adjuvant 1%.
Regulaid	Kalo Agricultural Chemicals, Inc.[b]	Polyethoxypolypropoxypropanol and alkyl 2-ethoxyethanol. Dihydroxy propane. Components ineffective as a spray adjuvant 9.4%.
Valent X-77	Valent USA Corp.[c]	Blend of alkylarylpolyoxyethylene glycols, free fatty acids and isopropanol. Components ineffective as a spray adjuvant 10%.

[a] 6075 Poplar Ave., Memphis TN 38119.
[b] 4550 W. 109 St., Overland Park KS 66211.
[c] PO Box 8025, Walnut Creek CA 94596.

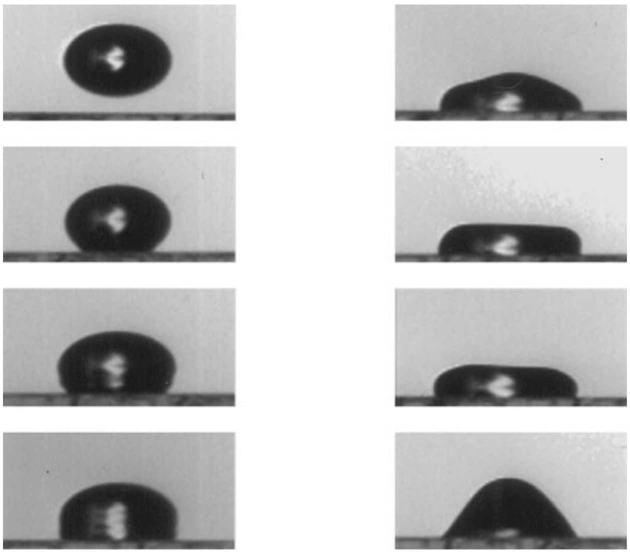

Fig. 3. Composite of videographs illustrating the impaction, deformation and initial recovery of 330-μm water droplets on a glass surface. Time interval between successive images was 0.1 ms.

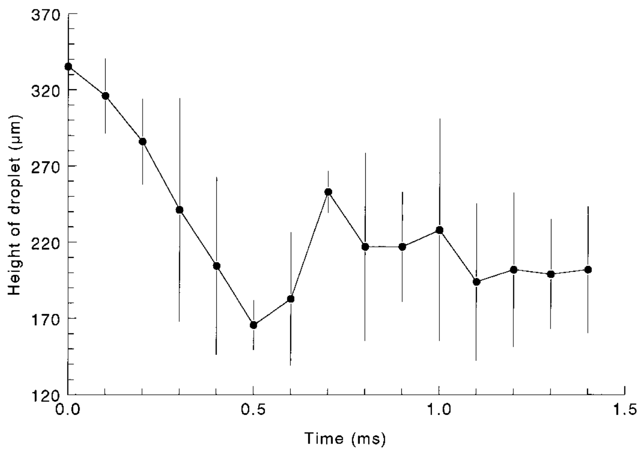

Fig. 4. Changes in water droplet (330 μm, 0.65 m s^{-1}) height with time during impaction on a glass microscope slide. Vertical bars refer to ± one standard deviation.

The changes in height, from 0.2 to 1.5 ms, were not statistically different. This was due to the variability among the five replicates and is indexed by the large standard deviation. The variability was probably due to timing errors associated with the pulsed nature of the proximity detector. It is likely that use of a proximity detector with a shorter delay between pulses would reduce these errors significantly.

This system is also suitable for determining changes in surface area during impaction, for accurately determining the contact angle of droplets, and for evaluating the characteristics of a droplet as it evaporates from a surface.

3.2 Single-droplet reflection (DOD generator)

3.2.1 Plant species and droplet size

Water, a common carrier for pesticide sprays, with the highest surface tension of all common liquids, is reflected from the leaves of many species while adhering to others. All aqueous droplets impacted on cabbage leaves were reflected, irrespective of droplet size (160–340 μm), whilst none of the droplets was reflected from the smooth, easy-to-wet pear leaves (Table 2). Greater reflection (as indexed by height and number) was observed from cabbage and wheat than from soybean and foxtail leaves at the largest droplet size. Only the largest droplets (340 μm) were totally reflected from the wheat surface, and droplet size did not appear to influence the number of droplets reflected from soybean and foxtail leaves. For a constant droplet size (and thus incoming velocity), the reflection heights differed significantly between plant species. An increase in droplet size resulted in a corresponding increase in reflection height for all species. Droplet reflection was species-dependent, varying from a four-fold increase in height for wheat when the incoming droplet size was increased from 160 to 340 μm, compared to only a 1.3-fold increase for soybean.

The adaxial surfaces of cabbage and wheat leaves are covered with hydrophobic crystalline epicuticular wax (the cabbage leaves were glabrous while the wheat had a low density of trichomes), while soybean and foxtail have pubescent leaf surfaces. If a droplet impacts a trichome directly it may not be reflected because the trichome may act as an energy absorber.

For cabbage, a relatively small change in velocity occurred during the impaction process (velocity of the reflected droplet was about 30% less than before impaction) compared to foxtail where the velocity decreased by 60–70%; for both species the change in velocity was independent of drop size (Table 3).

Some reflected droplets had sufficient energy for several reflections before stopping. Under field conditions, the droplets would either settle on a like target or be lost to the environment.

3.2.2 Intra-species differences

Intra-specific variation is illustrated in Fig. 5 where 10 individual water droplets (230 μm, 0.6 m s^{-1}) were impacted on either two leaves of different ages from the same plant or two different areas (that third of the leaf containing the leaf tip, and the middle third of the leaf) of the adaxial surface of the same leaf. It can be seen that the effect of droplet placement on reflection was entirely species-dependent. When the reflection from young versus old leaves was compared, less reflection was observed from young soybean leaves than from old ones, while the rebound from a young cabbage leaf was significantly greater than from a mature one. Similarly, the median part of the foxtail leaf showed twice the reflection of that for the leaf tip, while the leaf median gave lower reflection than the leaf tip for wheat leaves.

TABLE 2
Effect of Water Droplet Size on Theoretical Reflection Height from the Adaxial Leaf Surface of Selected Plant Species[a]

Plant	*Reflection height (cm) and (numbers rebounding (%))*								
	Droplet diameter (μm)								
	160			*230*			*340*		
Cabbage	0.58	a	(100)	0.96	a	(100)	1.17	a	(100)
Wheat	0.29	b	(80)	0.55	b	(70)	1.19	a	(100)
Soybean	0.32	b	(70)	0.36	b	(60)	0.43	b	(50)
Foxtail	0.18	bc	(50)	0.37	b	(80)	0.54	b	(70)
Pear	0.00	c	(0)	0.00	c	(0)	0.00	c	(0)

[a] Means separation by DMRT, means in columns with the same letter are not significantly different at the 5% level.
Adapted from Reference 24.

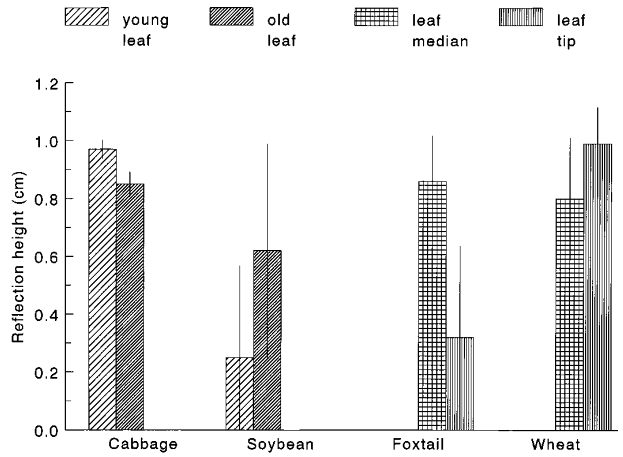

Fig. 5. Reflection height of water droplets (230 μm, 0.6 m s^{-1}) from different areas of leaves (adaxial surface) of selected plant species. Vertical bars refer to ± one standard deviation.

Reflection also varied with the species tested. Cabbage, for example, had little variation among replicates compared to soya, where the variability was large. These data illustrate the need for randomization and sufficient replication of plant material when investigating factors that affect droplet reflection, since variability due to leaf position and age could obscure differences among the variables being tested.

3.2.3 *Droplet velocity*

Reflection height of water droplets impacting on cabbage leaves increased linearly as impact velocity increased up to 0.90 m s^{-1} (Fig. 6). Beyond 0.90 m s^{-1} reflection height did not increase as incoming velocity increased. The reflection height of water droplets containing the surfactant 'Kinetic' (0.2 mg $litre^{-1}$) did not change with increase in incoming velocity. Most factors

TABLE 3
Comparison of Velocities of Incoming and Reflecting Water Droplets from Adaxial Leaf Surfaces of Selected Plant Species during Impaction[a]

Plant	*Droplet diameter (μm)*								
	160			*230*			*340*		
	Velocity (m s^{-1})			*Velocity (m s^{-1})*			*Velocity (m s^{-1})*		
	[b]*Inc.*	[c]*Ref.*	[d]*Lost*	[b]*Inc.*	[c]*Ref.*	[d]*Lost*	[b]*Inc.*	[c]*Ref.*	[d]*Lost*
Cabbage	0.47	0.33	29 c	0.59	0.43	27 c	0.69	0.48	31 c
Wheat	0.49	0.21	58 b	0.62	0.27	56 b	0.68	0.48	28 c
Soybean	0.48	0.21	59 b	0.62	0.20	68 b	0.68	0.19	71 b
Foxtail	0.48	0.13	74 b	0.61	0.25	59 b	0.71	0.26	63 b
Pear	0.49	0.00	100 a	0.62	0.00	100 a	0.70	0.00	100 a

[a] Means separation by DMRT, means in columns with the same letter are not significantly different at the 5% level.
[b] Velocity of incoming droplet.
[c] Velocity of reflected droplet, immediately after reflection.
[d] Velocity lost during impaction (%).

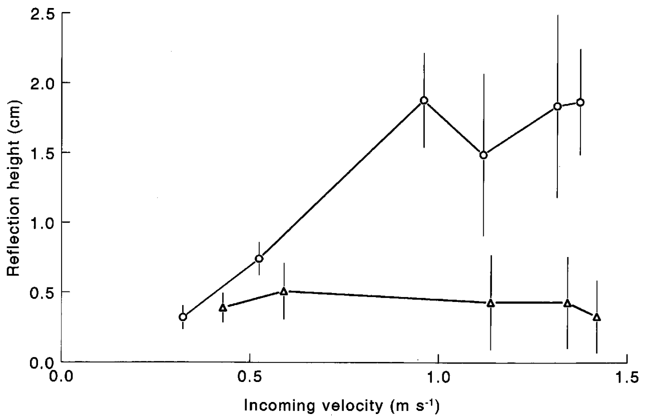

Fig. 6. Relationship between rebound height and incoming droplet velocity of 350 μm (○) water and (△) 0.2 mg litre^{-1} 'Kinetic' droplets on cabbage leaves. Vertical bars refer to ± one standard deviation.

affecting reflection in this study, except surface tension, were approximately equal for water droplets with and without surfactant. Therefore differences in reflection-height/incoming-velocity relationships were probably due to the difference in the surface tension of the liquids (72 and 29 mN m^{-1} for water and 0.2 mg litre^{-1} 'Kinetic', respectively). Lower surface tension of a liquid causes the droplet to spread more on impact (or even to fragment), which increases contact area and energy loss, and reduces energy stored in the newly created surface area. This reduces the energy imparted to a reforming droplet, and hence reduces reflection height. Preliminary results had indicated that concentrations of 'Kinetic' greater than 0.2 mg litre^{-1} gave zero reflection from cabbage leaves at droplet velocities less than 1.40 m s^{-1}.

3.3 Spray-cloud reflection (BL generator)

3.3.1 Effect of surfactant

Spray clouds of 260-μm droplets generated using the BL were impacted upon the adaxial surface of newly fully expanded cabbage leaves. Cabbage has a hard-to-wet surface and was chosen to provide a severe test on the effectiveness of the various surfactant at reducing rebound. Additional experimentation is needed to determine whether the results below would be obtained from other plant surfaces, or whether there is a surfactant species interaction.

All surfactants reduced the number and height of reflected droplets compared to water only. Thus, the potential for improving spraying efficiency was increased and off-target contamination reduced. There was a five-fold difference in reduction of reflection height between the most and least effective surfactants (Table 4). Surfactants are added to formulations for a variety of reasons, including improving the efficacy of the active ingredient(s), maintaining efficacy with less active ingredient, increasing the wetting, spreading or adhesion properties, and acting as emulsifying or dispersing agents in spray tank mixtures. Thus, reducing reflection may not be the primary reason for using a surfactant, but an additional benefit of using surfactants is to improve droplet capture.

TABLE 4
Effect of Surfactants (1.25 mg litre^{-1}) on Reflection of Aqueous Droplets (260 μm, 7 m s^{-1}) from the Adaxial Surface of Cabbage Leaves[a]

Surfactant	*Height of reflection (cm)*	*Reduction in reflection height (%)*	*Numbers reflected*	*Reduction in no. reflected (%)*
Water	1.96 a		88.4 a	
Agridex	1.67 b	15.0	65.8 b	25.6
Induce	1.35 c	31.1	51.9 c	41.3
Valent X-77	1.20 d	38.6	46.4 c	47.5
Regulaid	0.79 e	59.9	26.8 d	69.7
Kinetic	0.46 f	76.6	14.9 e	83.1

[a] Means separation by DMRT, means in columns with the same letter are not significantly different at the 5% level. Adapted from Reference 24.

3.3.2 Effect of surfactant concentration

There was good correlation between concentration of the surfactant 'Kinetic' and rebound height (Fig. 7). Rebound was not eliminated at the concentrations tested but it was reduced significantly at the higher rates.

Impaction is a dynamic process with the droplet remaining on a leaf for less than 1 ms.[3,14] The droplet undergoes extensive deformation during which new surface is formed in a short time and unless surfactant

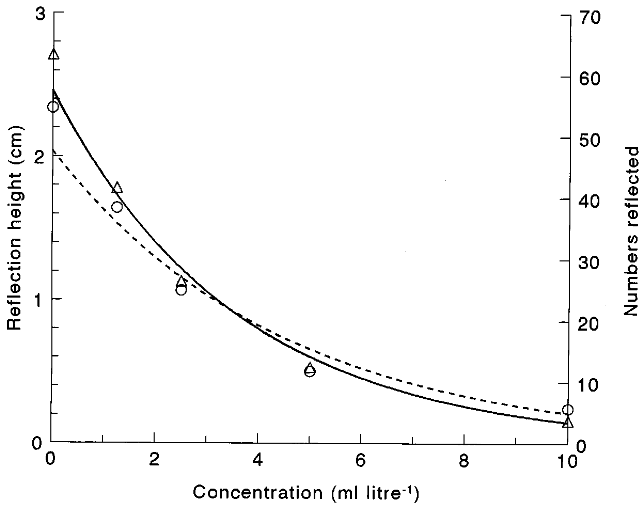

Fig. 7. Effect of increasing surfactant (Kinetic) concentration on (○) height ($y = 2.5 - 2.8 \ln x$, $r^2 = 0.992$) and (△) number ($y = 47.6 - 2.3 \ln x$, $r^2 = 0.963$) of water droplets (230 μm, 7 m s^{-1}) reflected from the adaxial surface of wheat leaves. Separation of means for each concentration significant at the 5% level, using DMRT.

molecules are present at the new surface, or can diffuse to it during droplet deformation, surface tension will not be reduced and the surfactant will not reduce rebound. As the surfactant concentration is increased, more surfactant molecules will reach the newly created surface during the impaction-process time. When this occurs, surface tension will be lowered and reflection will decrease.

4 CONCLUSIONS

In this study, quantitative differences in reflection were obtained from a number of parameters, namely plant species, droplet velocity and size, surfactant type and concentration.

Combining the video-motion analysis system with either a single or spray monosized droplet generator resulted in a versatile system for examining droplet impaction. By using low magnification and the BL generator, the system could be used as either a fast, qualitative technique for assessing large differences in reflection of a spray cloud, or more quantitatively by determining reflection height and number of droplets reflected. With the DOD generator, detailed information on the incoming and outgoing velocity, along with reflection height, of individual droplets could be obtained. By using the DOD generator and high magnification, droplet impaction and subsequent deformation could be examined.

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